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Optical and near-infrared observations of Anomalous X-ray Pulsars

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Abstract. We present recent results of our program of deep optical and infrared observations of AXPs. We find that the counterpart to AXP 4U 0142+61 has a peculiar spectral energy distribution. The counterpart is remarkably bright in the near-infrared, but is not detected in the B band. We also present the possible detection of a second AXP counterpart, namely that to 1E 2259+586.

1. Introduction

Anomalous X-ray Pulsars (AXP) are mysterious objects. We do not understand the energy source that is responsible for their X-ray emission; unlike young Crab-like pulsars their spin-down energy is insufficient and unlike binary X-ray pulsars there is no sign of binary companions from which they could accrete. In the two models most often considered AXP are either isolated neutron stars accreting from a fossil disk, formed out of supernova debris (e.g. Chatterjee, Hernquist & Narayan 2000) or after a common envelope phase (van Paradijs, Taam & van den Heuvel 1995), or magnetars, neutron stars with an ultrahigh magnetic field ($B > 10^{14}$ Gauss, Thompson & Duncan 1996).

Keck data of 4U 0142+61, the X-ray brightest AXP, revealed a faint $R = 24.99 \pm 0.07$ source within the 3.9 arcsec radius *Einstein* error circle[1], that has peculiar optical colours, $V-R = 0.63\pm0.11$, $R-I = 1.15\pm0.09$ (Hulleman et al. 2000). By comparing Keck images from 1994 and 1999 we found its brightness to be constant to within 0.2 mag (2σ) in R and its proper motion to be less than 0.03 arcsec per year (again 2σ).

2. Recent results

2.1. The spectral energy distribution of AXP 4U 0142+61

We have extended our data set of 4U 0142+61 with photometry in the optical B band and the near-infrared K band. The source is brighter than expected in K ($K = 19.6$, Fig. 1), but it is not detected in the B band. None of the currently available models can explain the observed optical emission (Fig. 2), although

[1](C. Kouveliotou (priv. comm.) informed us that the source is also within the smaller *Chandra* error circle. See also the contribution by Juett et al. in these proceedings.

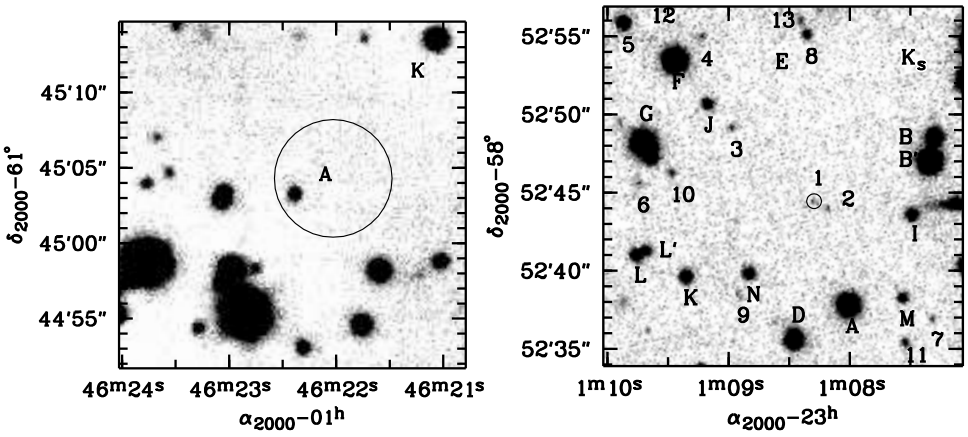

Figure 1.
Left: Near-infrared image of the field around AXP 4U 0142+61. Overplotted is the *Einstein* error circle (White et al. 1987). Star A is the counterpart.
Right: Near-infrared image of the field around AXP 1E 2259+586. The circle represents the *Chandra* position. See Hulleman et al. (2001) for details.

we note that no model for the optical emission from a magnetar is currently available.

2.2. A possible second AXP counterpart.

Recently a subarcsecond position has been derived for AXP 1E 2259+586 using *Chandra* data (Hulleman et al. 2001). Within the error circle we find a faint near-infrared source ($K_s = 21.7 \pm 0.2$). It is not detected in the J, I and R bands. We set limits of 23.8, 25.6 and 26.4 mag in J, I and R respectively. Finally, we note that the near-infrared to X-ray flux ratio is similar for both AXPs.

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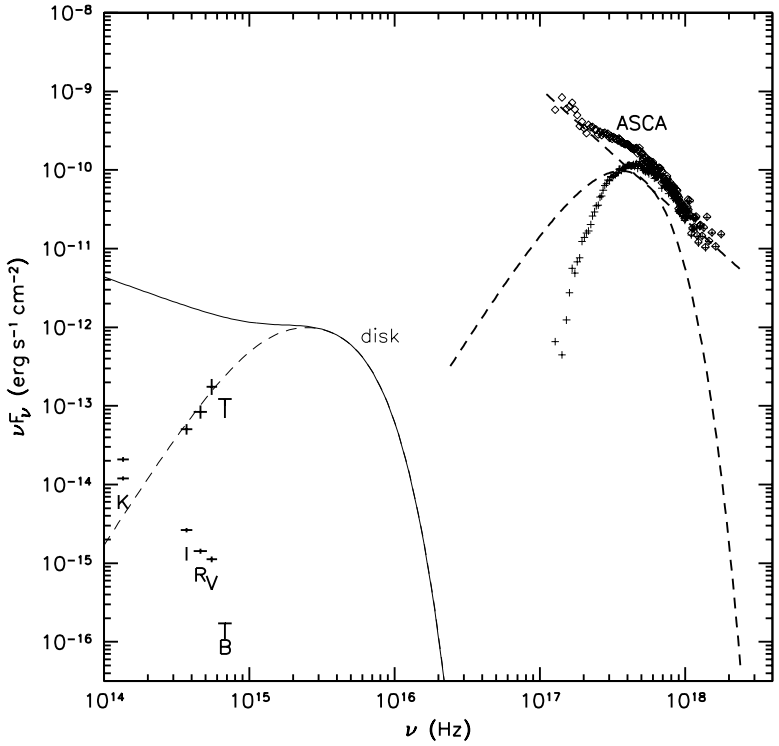

Figure 2. Observed and extinction corrected fluxes from AXP 4U 0142+61. Also shown are the unabsorbed blackbody and power-law components of the model that best fits the X-ray spectrum. Overplotted are models of the optical emission of a large disk around an isolated neutron star (solid line) and of a small disk in a compact binary (thin dashed line).